

Electronegative Gas Thruster - Direct Thrust Measurement

Completed Technology Project (2013 - 2014)



Project Introduction

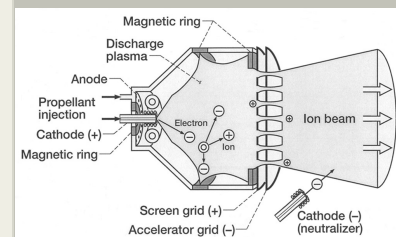
This effort is an international collaboration and academic partnership to mature an innovative electric propulsion (EP) thruster concept to TRL 3 through direct thrust measurement. The initial target application is for Small Satellites, but can be extended to higher power. The Plasma propulsion with Electronegative GASES (PEGASES) concept simplifies ion thruster operation, eliminates a neutralizer requirement and should yield longer life capabilities and lower cost implementation over conventional gridded ion engines. The basic proof-of concept has been demonstrated and matured to TRL 2 over the past several years by researchers at the Laboratoire de Physique des Plasma in France. Due to the low maturity of the innovation, there are currently no domestic investments in electronegative gas thrusters anywhere within NASA, industry or academia. The end product of this Center Innovation Fund (CIF) project will be a validation of the proof-of-concept, maturation to TRL 3 and technology assessment report to summarize the potential for the PEGASES concept to supplant the incumbent technology.

Information exchange with the foreign national will be one-way with the exception of the test results. Those test results will first go through a standard public release ITAR/export control review, and the results will be presented in a public technical forum, and the results will be presented in a public technical forum.

The innovation of the PEGASES concept is the simplification of gridded ion technology and elimination of the neutralization requirement through negative gas propellant utilization and alternating accelerating potential.

Conventional EP is an enabling technology for a wide range of missions. The currently available solutions include conventional gridded-ion thrusters and Hall thrusters. For science, the Dawn mission used EP to enable a single science instrument suite to rendezvous with two distinct targets within a Discovery class mission. Electron collisions are used to ionize a heavy gas (e.g. xenon) and accelerate the positive xenon ions using an electrostatic field and then an external cathode is used to neutralize the exhaust. Gridded-ion thrusters have three independent feed system elements for the discharge (ionization) cathode, the main propellant flow, and the neutralization cathode.

There has been a strong push within the planetary community to move to Hall thrusters because gridded-ion thrusters are considered unaffordable within the Discovery mission cost cap without additional incentive funding. In fact, the market has been driving nearly all EP solutions to Hall thrusters due to the higher thrust-to-power potential and reduced system complexity (i.e. cost). Hall thrusters have two independent feed system elements for the main propellant flow (though the anode) and the cathode. The basic principle of operation is similar to that of a gridded-ion thruster. However, instead of grids, a magnetic field is used to trap electrons via the Hall Effect which



Direct Thrust Measurement will be Applied to a Conventional Ion Engine

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creates an electrostatic field and functions as a grid-less ion engine. The electron source is an external cathode also used for neutralization.

Hall thrusters are typically lower efficiency than gridded-ion thrusters, but the reduced complexity, cost, and higher thrust-to-power make them attractive. While they operate at 5-10% lower efficiency, they still offer an order of magnitude increase in specific impulse over chemical alternatives. Consider the Dawn spacecraft will obtain 12km/s ΔV from the NSTAR thruster with ~400kg of Xenon and is comparable to the ΔV from ~200,000kg propellant of the launch vehicle. A Hall thruster would require closer to 450kg of propellant, but reduce the total spacecraft cost by \$15M; a significant fraction for a Discovery mission vehicle.

The community continues to investigate evolutionary concepts on both the gridded-ion and Hall thruster technologies. Center level and program level technology funding has been applied to investigate alternative grid materials, new magnetic field topologies, alternative cathode emitter materials, alternative propellants, etc. However, the PEGASES concept is revolutionary by eliminating all cathodes and leveraging an electronegative gas to produce both positive and negative ions. In the proposed thruster, one of the grids is alternately biased to achieve thrust from both the positive and negative species. The resulting electronegative gas thrusters only have one feed element, and can leverage an RF source to generate both positive and negative ions. The advantages of the PEGASES concept include:

Eliminating the dependence on cathodes sensitive to propellant contamination

Propellant cost reduction; 99.5% purity is 80% lower cost than 99.999%; ~\$M per mission

Propellant handling and loading costs / process simplification; >\$M per mission

Increasing recombination speed over ions and electrons (i.e. reduced spacecraft plume interactions)

Reducing charge exchange erosion (i.e. increase grid life)

Eliminating of two additional feed system lines

Eliminating of external neutralization

Cost Enabling gridded-ion technology for Small spacecraft

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Marshall Space Flight Center (MSFC)

Responsible Program:

Center Innovation Fund: MSFC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

John W Dankanich

Project Manager:

Andrew Keys

Principal Investigator:

John W Dankanich

Co-Investigators:

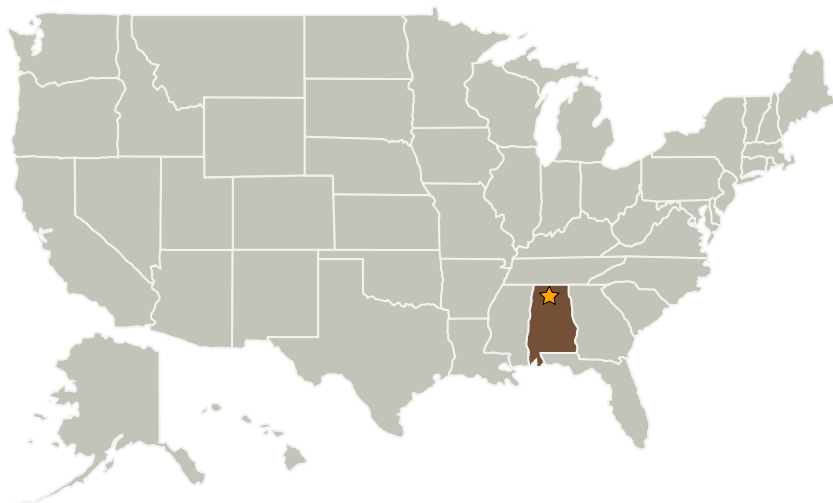
Ane Aanesland
Kurt A Polzin
Mitchell L Walker

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Primary U.S. Work Locations and Key Partners



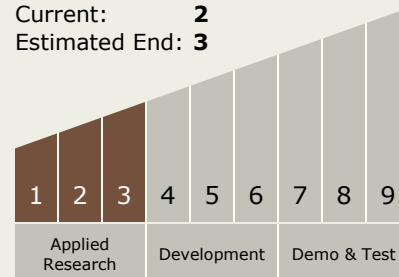
Organizations Performing Work	Role	Type	Location
★ Marshall Space Flight Center (MSFC)	Lead Organization	NASA Center	Huntsville, Alabama
Georgia Institute of Technology-Main Campus (GA Tech)	Supporting Organization	Academia	Atlanta, Georgia
Laboratoire de Physique des Plasmas, Ecole Polytechnique	Supporting Organization	Academia	Palaiseau, Outside the United States, France

Primary U.S. Work Locations

Alabama

Technology Maturity (TRL)

Start: **1**
 Current: **2**
 Estimated End: **3**



Technology Areas

Primary:

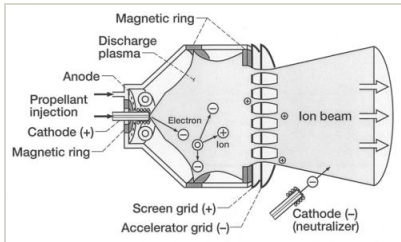
- TX01 Propulsion Systems
 - TX01.2 Electric Space Propulsion
 - TX01.2.2 Electrostatic

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Images



Dankanich - 1

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(<https://techport.nasa.gov/image/5031>)